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A North Carolina Field Study to Evaluate Greenroof Runoff Quantity, Runoff Quality, and Plant Growth

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www.bae.ncsu.edu/greenroofs



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Special Thanks to

Mike Regans

Emory Knoll Farms

American Hydrotech

Carolina Stalite

Wayne Community College

City of Kinston

NCDENR



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Stormwater Best Management Practices—BMPs

- Several Stormwater BMPs are in practice throughout North Carolina
 - Bio-retention Areas
 - Sand Filters
 - Wet Ponds
 - Riparian Buffers
 - Constructed Wetlands
 - Pervious Pavement
 - Greenroofs



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Research Goals

- To help develop greenroof design standards in North Carolina through:
 - Estimating percent of precipitation retained
 - Curve Number
 - Determining reductions in peak flow of runoff
 - Rational C
 - Discovering any nutrient removal benefits
 - Determining which plants thrive in the NC environment
 - Finding an optimal soil depth for vegetation growth within the first year



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Greenroof Field Site Locations

- Two greenroof research sites are located in eastern North Carolina. Both sites are within the Neuse River Basin.



Kinston, Lenoir County

Goldsboro, Wayne County

■ Study Site County

■ Wake County (home of NCSU)



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Field Site Description: Goldsboro, NC

- Wayne Community College Greenroof
 - Constructed in May 2002
 - Extensive greenroof
 - 750 ft² area, relatively flat
 - 2 in. and 4 in. soil media depths
 - Hydrodrain 300™ Drainage Layer
 - Planted with a variety of *Sedum* and *Delosperma* species



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Field Site Description: Kinston, NC

- Neuseway Nature Center Greenroof
 - Constructed in April 2002
 - Extensive greenroof
 - 290 ft², 3% pitched roof
 - 4 in. soil media depth
 - Floradrain FD40™ Drainage Layer
 - Planted with a variety of *Sedum* species



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Monitoring the Sites

- Each site has:
 - Two Sigma 900Max™ Automatic Samplers to retrieve water quality samples of greenroof and control roof runoff and measure runoff flow data
 - A tipping bucket rain gage to measure rainfall for each storm event
 - A container to collect rain samples for water quality analysis





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Hydrologic Results: Water Retention

- Water retention was measured at each site for each rainfall event
 - The water retention for each rain event was determined as follows:

$$P_{\text{retained}} = P_{\text{rainfall}} - P_{\text{runoff}}$$

Where: P_{retained} = Precipitation retained (in.)

P_{rainfall} = Precipitation of rain event (in.)

P_{runoff} = Runoff depth from greenroof (in.)



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Water Retention Data Summary

- Goldsboro Greenroof (April – December 2003)

Total Rainfall	Total Amount Retained	Total Percent Retained
35.5 in.	21.9 in.	62%

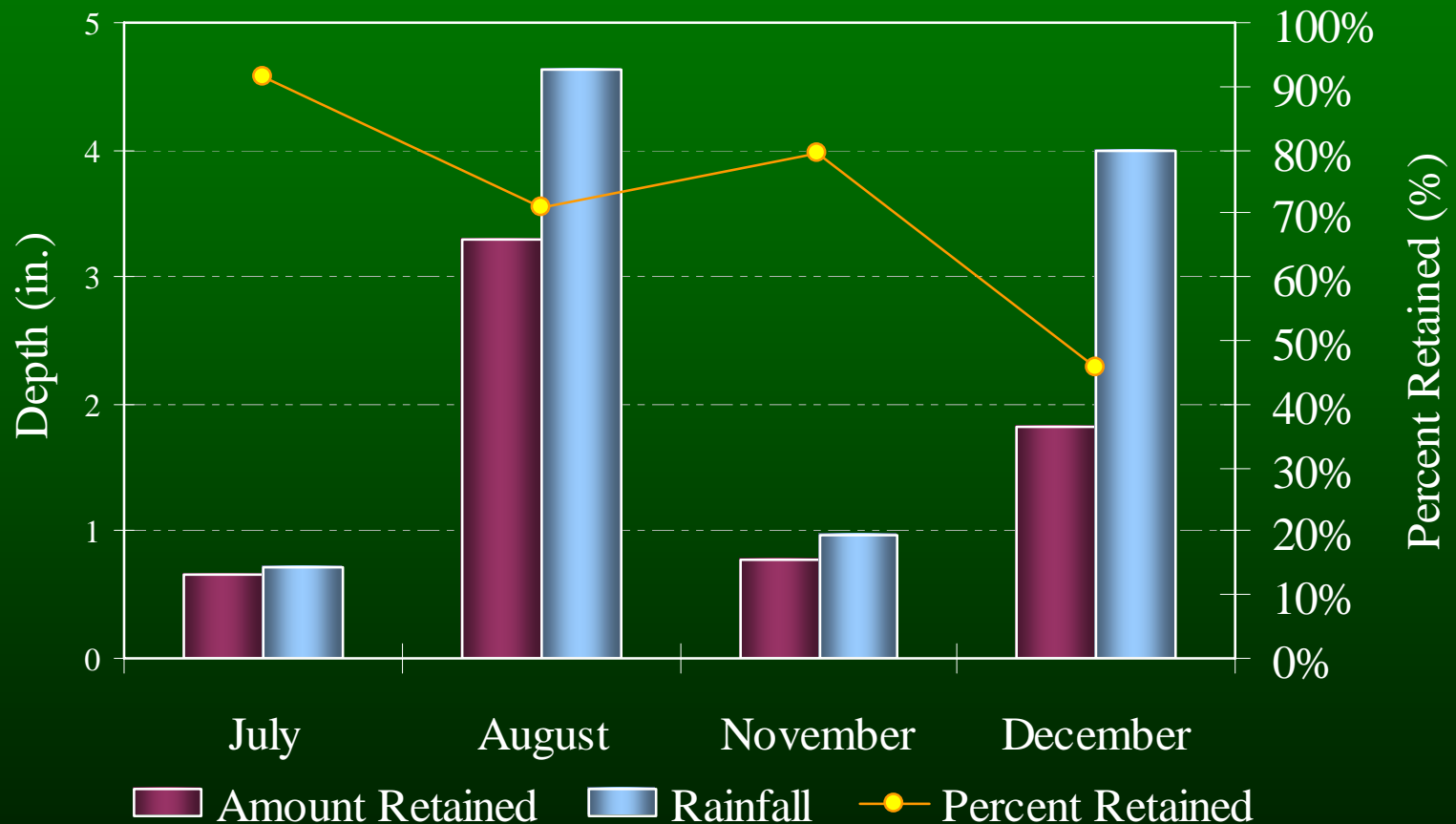
- Kinston Greenroof (July – August 2003 & November – December 2003)

Total Rainfall	Total Amount Retained	Total Percent Retained
10.3 in.	6.5 in.	63%



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Monthly Retention Rates in 2003: Kinston, NC





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Hydrologic Results: Peak Flow Reduction

- Peak flow reduction was measured by comparing the greenroof runoff peak flow (gpm) with the peak rainfall rate onto the greenroof (gpm)
 - Flow rates were not measured from the control roof at each site
- Average peak flow reductions of 70% to 95% were observed at each greenroof site



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Hydrologic Conclusions

- Both greenroofs retained a significant portion of the precipitation ($\alpha < 0.05$)
 - Average retention at Goldsboro greenroof was 62%
 - Average retention at Kinston greenroof was 63%
- Both greenroofs significantly reduced the peak flow of runoff ($\alpha < 0.05$)
 - Average peak flow reduction at Goldsboro greenroof was 78%
 - Average peak flow reduction at Kinston greenroof was 87%



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Hydrologic Design

■ Curve Number

- A number ranging between 0 and 100 to describe the permeability of a land type
- Used in the SCS Curve Number Method to predict the depth of runoff observed in a given watershed

$$RO = \frac{[P - (0.2)(S)]^2}{P + (0.8)(S)}$$

RO = Greenroof runoff (in.)

P = Precipitation (in.)

S = $1000/\text{CN} - 10$

CN = Curve number



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Hydrologic Design — CN

- Curve Numbers of 5 Largest Rain Events at WCC Greenroof in Goldsboro, NC

Date	Rainfall	Runoff	Retained	CN
4-9-2003	1.63 in.	1.11 in.	32%	95
7-13-2003	1.70 in.	0.69 in.	59%	87
7-23-2003	3.05 in.	1.88 in.	38%	88
10-28-2003	2.29 in.	0.71 in.	69%	79
12-10-2003	1.52 in.	0.71 in.	53%	90

Average CN = 88



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Hydrologic Design

■ Rational Coefficient

- A decimal ranging from 0 to 1 to describe the permeability of a land use
- Used in the Rational Method to predict the peak flow of runoff in small watersheds

$$Q = CIA$$

Q = Peak runoff (cfs)

C = Rational coefficient

I = Rainfall intensity (in./hr)

A = Watershed area (ac)



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Hydrologic Design — Rational C

- Rational Coefficients of 5 Largest Rain Events at WCC Greenroof in Goldsboro, NC

Date	Rainfall	Runoff	Retained	C
4-9-03	1.63 in.	1.11 in.	32%	0.77
7-13-02	1.70 in.	0.69 in.	59%	0.35
7-23-03	3.05 in.	1.88 in.	38%	0.87
10-28-03	2.29 in.	0.71 in.	69%	0.21
12-10-03	1.52 in.	0.71 in.	53%	0.53

Average Rational C = 0.55



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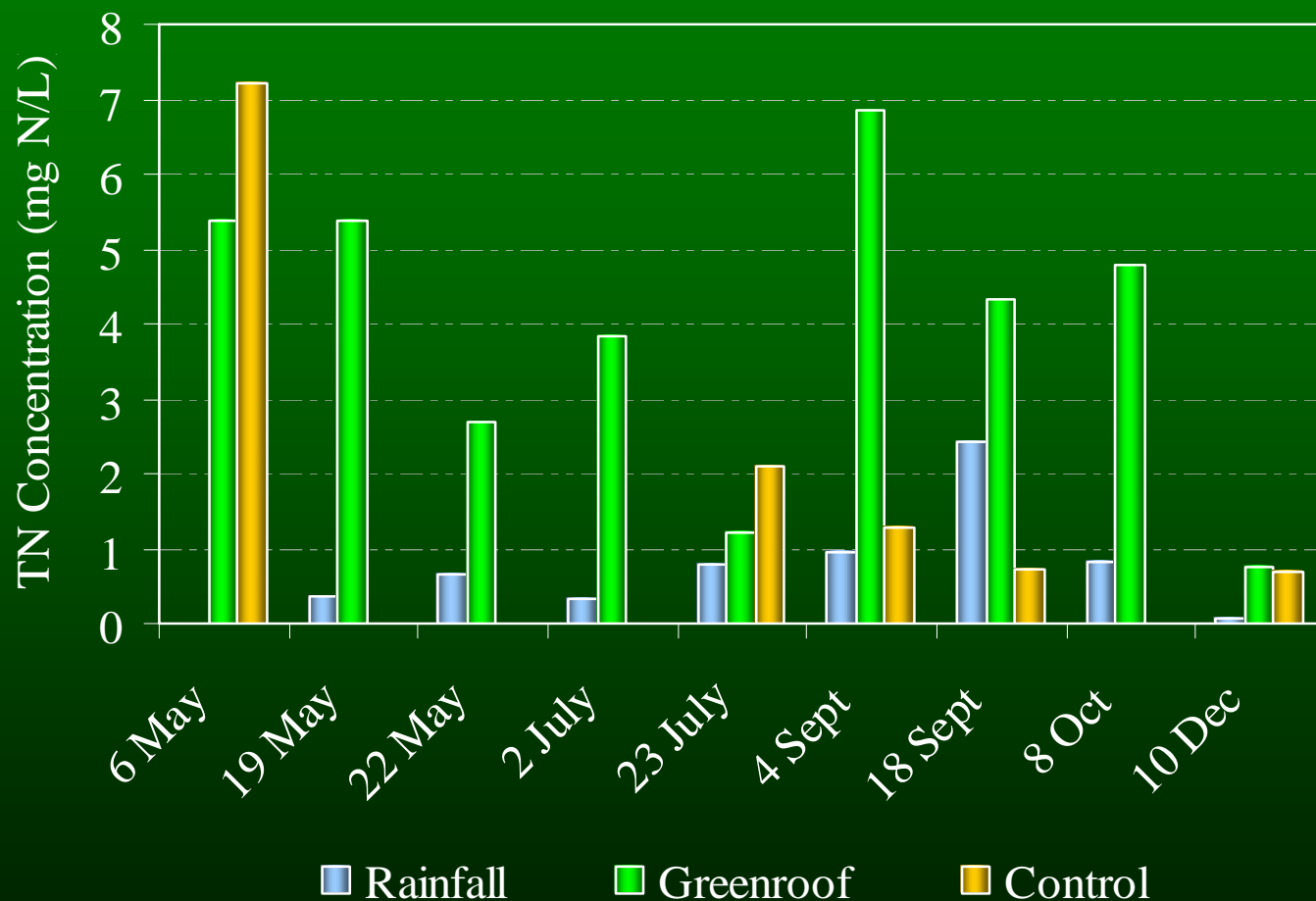
Water Quality Results

- Total Nitrogen (TN)
 - In most cases, the TN concentration was higher in the greenroof runoff than the rainfall and the control roof runoff
 - There was no consistent pattern observed in the TN mass loading observed in the greenroof runoff
- Total Phosphorus (TP)
 - The TP concentration and mass loading were consistently higher in the greenroof runoff



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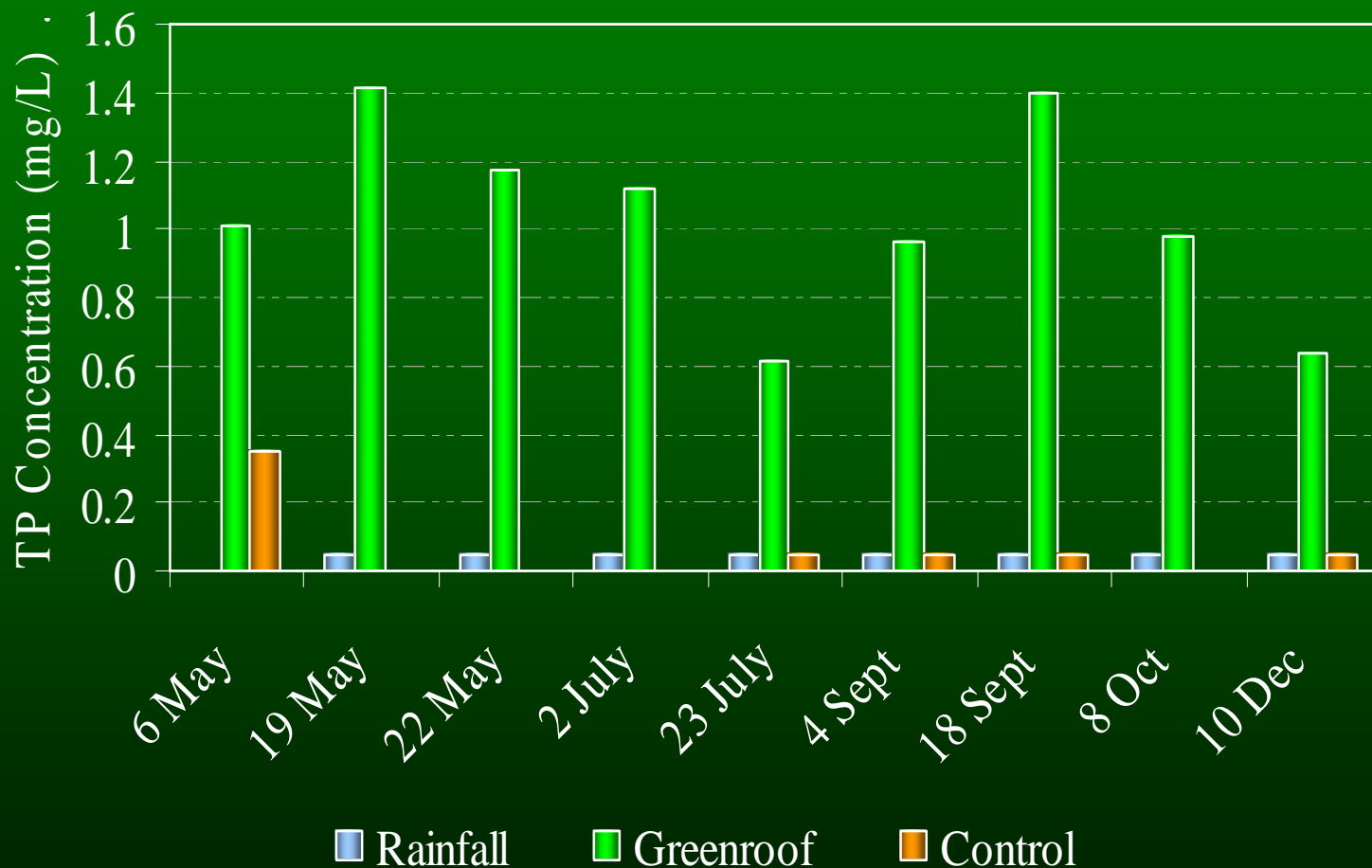
Water Quality Results: TN Concentration





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Water Quality Results: TP Concentration





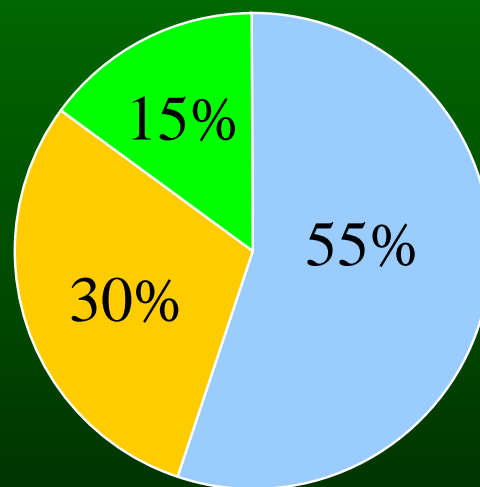
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Soil Media Composition

■ Carolina Stalite's Perma Till Lightweight Roof Garden Soil Mix

- 5/16" Perma Till Expanded Slate
- Approved Compost
- Rootzone Sand

- Perma Till
- Rootzone Sand
- Compost





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Design Recommendations

- The average CN for observed rain events greater than 1.5 in. was 88
- The average Rational C for observed rain events greater than 1.5 in. was 0.55
- No design recommendations can be made for nutrient removal
- A 4 in. deep greenroof will provide faster plant growth in the first year
 - Plant stabilization within the first year is the most important



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Design Recommendations

- Plant species recommended for growth in eastern and central North Carolina
 - *Sedum album*
 - *Sedum album murale*
 - *Sedum floriferum*
 - *Sedum reflexum*
 - *Sedum sexangulare*
 - *Sedum spurium fuldaglut*
 - *Delosperma nubigenum*



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Questions?

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for more information**

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